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breath. When this inhalation of breath had been carried on for a considerable time the patient was passed three times under the belly and over the back of the brute."

Ringworm: "The common cure for this disease was rubbing with silver. The modes of rubbing were various."

Warts: "Wrap up in a parcel as many grains of barley as there are warts, and lay it on the public road. Whoever finds and opens it inherits the warts.

"Rub the warts with a piece of raw meat, bury it, and as it decays the warts disappear.

"Wash the warts with water that has collected in the hollow parts of a *layer-stone.*"

Eye Disease: "Catch a live frog and lick the frog's eyes with the tongue. The person who does so has only to lick with the tongue any diseased eye, and a cure is effected." Compare this with the cure for burns.

Rheumatism: "Those who were born with their feet first possessed great power to heal all kinds of sprains, lumbago and rheumatism, either by rubbing the affected part or by trampling on it. The greater virtue lay in the feet."

On the Henry Draper Memorial Photographs of Stellar Spectra. By George F. Barker.

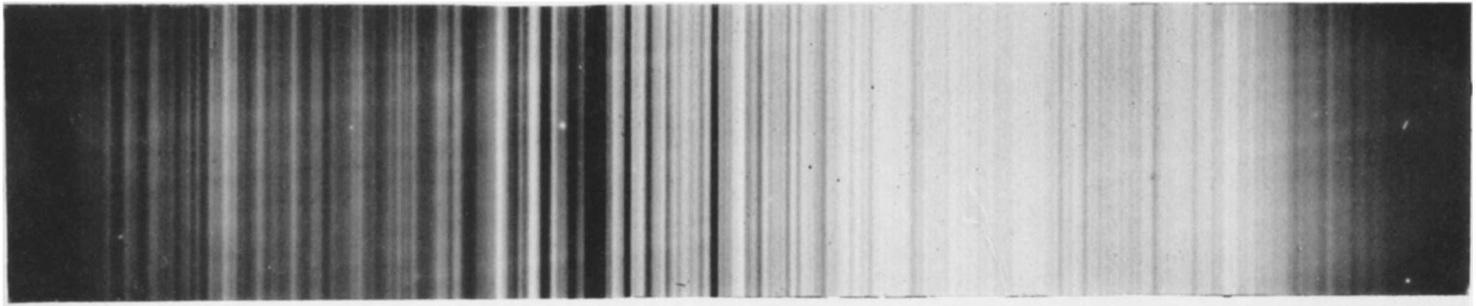
(Read before the American Philosophical Society, April 1, 1887.)

By the courtesy of Prof. Edward C. Pickering, Director of the Harvard College Observatory, I have the pleasure of exhibiting to the members of the American Philosophical Society some of the remarkable photographs of stellar spectra which have been recently taken under his direction, and which form part of an original research to be called the Henry Draper Memorial.

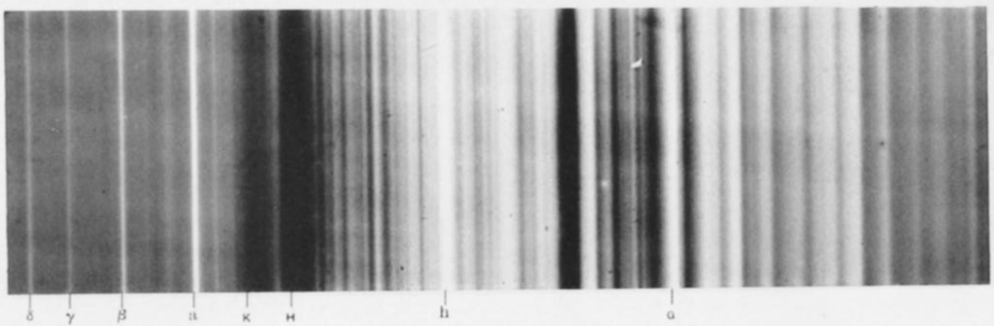
The first photograph of a stellar spectrum ever taken was that of the star Sirius (α Canis majoris), obtained by Dr. Huggins in 1863. But, as he says, it was scarcely more than a stain on the plate, and showed no indications of fixed lines.* The first spectrum photograph showing distinct lines, was obtained by Dr. Henry Draper in 1872. The star photographed was Vega (α Lyræ), and the spectrum showed four strong lines toward the more refrangible end. It was taken with the twenty-eight inch reflecting telescope which Dr. Draper had himself constructed. Subsequently he used for this purpose the twelve inch refractor which he had obtained from A. Clark & Sons in 1875. Up to the year 1877, he had taken, beside α Lyræ, the spectra of α Aquilæ, Arcturus, Capella, the moon, Venus, Mars and Jupiter.† In 1880 this refractor was exchanged for another, also

* Phil. Trans., 1864, 428.

† Am. J. Sci., III, xviii, 419, 1879.



α TAURI. 2 PRISMS.



o CETI. 1 PRISM.

made by the Clarks, but which, although of slightly less aperture—half an inch—was provided with a photographic correcting lens. The large amount of work done with these instruments appears from the fact that at the time of his death in 1882, he had taken more than a hundred stellar spectrum photographs, the later ones having a comparison spectrum upon the same plate. The methods employed both by Dr. Huggins and by Dr. Draper in all their later work were in general the same. The light of the star was concentrated by the object glass of a large telescope upon the slit of a spectroscope placed at its focus. In consequence, a narrow slit was necessary in order to obtain good definition, and very perfect adjustment of the driving clock was required to keep the image of the star upon the slit. The spectra thus obtained were of course quite minute; being about half an inch only in length, and only one sixteenth or thereabouts in width. Dr. Huggins made use of a cylindrical lens placed in front of the slit to obtain the necessary width to the spectrum. But Dr. Draper secured this end by throwing the image of the star slightly out of focus.

The first attempts to obtain photographs of stellar spectra which were made at the Harvard College Observatory were undertaken in May, 1885, by the aid of an appropriation from the Rumford fund of the American Academy of Arts and Sciences. In these experiments an entirely new photographic method was adopted. The prism was placed in front of the object glass of the telescope; a plan originally suggested for eye-observations by Fraunhofer in 1823* and employed subsequently, practically, by Secchi and Respighi. The advantages, for photographic purposes, of this method are two-fold: First, the loss of light is extremely small; and second, the stars over the entire field of the telescope will impress their spectra upon the plate. Hence while previous observers could photograph but one star at a time, and this satisfactorily only with stars of the first or second magnitude, more than one hundred spectra have now been simultaneously obtained on a single plate, many of them of stars no brighter than the seventh or eighth magnitude. The earliest photographs obtained at the Observatory were taken by placing a prism whose refracting angle was 30° in front of a Voigtländer photographic lens of two inches aperture and about seven inches focal length. No clock-work was used, the spectra being formed of the trails of the stars. In the spectrum of the Pole-star thus taken, over a dozen lines could be counted; and in the spectra of α Lyræ and α Aquilæ, the characteristic lines were shown, even when the time of exposure was only two or three minutes.

In the autumn of 1885, an appropriation was made from the Bache fund of the National Academy of Sciences for the purpose of continuing these investigations. A prism of 15° refracting angle and eight inches in clear aperture was employed, placed in front of a Voigtländer photographic lens having an aperture of eight inches and a focal length of about forty-five inches. The details of the method are thus described in the report of Prof. Pickering :†

* See Schellen's Spectrum Analysis, English ed., 1872, p. 462, et seq.

† Memoirs Am. Acad. Arts and Sci., xi, 209, 1886.

"The prism was always placed with its edges horizontal when the telescope was in the meridian. The spectrum then extended north and south. If clock-work was attached, a line of light would be formed, too narrow to show the lines of the spectrum satisfactorily. The usual method of removing this difficulty is the employment of a cylindrical lens to widen the spectrum; but if the clock-work is disconnected, the motion of the star will produce the same effect. Unless the star is very bright, the motion will, however, be so great that the spectrum will be too faint. It is only necessary to vary the rate of the clock in order to give any desired width to the spectrum. A width of about one millimeter is needed to show the fainter lines. This distance would be traversed by an equatorial star in about twelve seconds. The longest time that it is ordinarily convenient to expose a plate is about an hour. If then the clock is made to gain or lose twelve seconds an hour, it will have the rate best suited for the spectra of the faintest stars. A mean time clock loses about ten seconds an hour. It is only necessary to substitute a mean time clock for the sidereal clock to produce the required rate. It was found more convenient, however, to have an auxiliary clock whose rate could be altered at will by inserting stops of various lengths under the bob of the pendulum. One of these made it gain twelve seconds in about five minutes, the other produced the same gain in an hour. The velocity of the image upon the plate when the clock is detached could thus be reduced thirty or three hundred and sixty times. This corresponds to a difference of 3.7 and 6.1 magnitudes respectively. Since the spectrum of a star of the second magnitude could be taken without clock-work, stars of the sixth and eighth magnitudes respectively could be photographed equally well with the arrangement described above."

The work already undertaken in this direction developed so rapidly that the Bache appropriation soon proved entirely inadequate to carry it further. Whereupon early in 1886, Mrs. Henry Draper, who from the first had taken a great interest in this work as a continuation of that so auspiciously begun by Dr. Draper himself, generously came forward and agreed to place at Prof. Pickering's disposal, not only the excellent eleven inch photographic telescope which Dr. Draper had so successfully used in his spectrum researches, but also a sufficient sum of money to enable the experiments already suggested to be fairly tried. In consequence, Prof. Pickering decided to continue the investigation along three more or less independent lines: First, he purposed to make a general survey of stellar spectra, each spectra being photographed with an exposure of not less than five minutes. These photographs exhibit in general the spectra of all stars brighter than the sixth magnitude, with sufficient distinctness for measurement. Second, he desired to undertake a determination of the spectra of the fainter stars, each photograph of this set receiving an exposure of an hour. All stars not fainter than the ninth magnitude, and included in a region ten degrees square, are represented upon a single plate. The work in both these directions has been done thus far with the Bache

photographic telescopes, 15,729 spectra having been already photographed and measured. Third, he decided to carry on a more careful study of the spectra of the brighter stars. For this work, the Draper eleven inch corrected refractor was specially used, a suitable observatory having been erected for it in Cambridge. Four prisms, each having a refracting angle of 15°, were constructed, of which three had a clear aperture of nearly eleven inches, the fourth being somewhat smaller. These four prisms with their mounting weighed more than a hundred pounds and occupied a cubic foot of space.

The original negatives have been enlarged by a novel process which gives most excellent results. A cylindrical lens is placed close to the enlarging lens with its axis parallel to the length of the spectrum. In the apparatus actually employed the length of the spectrum and with it the dispersion, is increased five times, while the breadth is increased nearly one hundred. This arrangement has the great advantage that it greatly reduces the difficulty arising from the feeble light of the star. Until recently, the spectra in the original negatives were made very narrow, since otherwise the intensity of the starlight would have been insufficient to produce the proper decomposition of the silver particles. The enlargement being made by daylight, the vast amount of energy then available is controlled by the original negative, the action of which may be compared to that of a telegraphic relay. The copies therefore represent many hundred times the original energy received from the stars.

It was with the apparatus above described and under these conditions, that the photographs were taken that I have the honor of exhibiting to the Society. Although the earliest satisfactory results were obtained in October, 1886, yet it is evident that the full meaning of these photographs can be discovered only after they have been carefully measured, and after these measurements have been reduced and thoroughly discussed. Some points of interest, however, appear on simple inspection of them. This photograph of α Cygni for example, which was taken November 26, 1886, shows the H line to be double,* its two components having a difference of wave-length of about one ten-millionth of a millimeter. This photograph of o Ceti shows the lines G and h as bright lines, as well as the four ultra violet lines which are the characteristic of spectra of the first type; to which Dr. Huggins gave the letters α, β, γ and δ. In this spectrum, however, the H and K lines are seen to be dark; showing that they do not belong to that series of lines. The spectrum of α Tauri shows a multitude of lines and bands, massed in the more refrangible region; thus accounting for the ruddy color of the star. The spectrum of Sirius shows, besides the well-known broad lines characteristic of this brilliant star, a large number of fainter ones. The spectrum of α Canis minoris, taken with four prisms, shows the solar dark lines G, h, H and K.

This entire research is entitled "The Henry Draper Memorial." The

* According to Young, the line H in the solar chromosphere, which is bright, is double also.

first annual report has just been issued by Prof. Pickering and contains an account of the investigations thus far made, together with the results obtained. It is illustrated with a plate (which I have the pleasure of placing before you) illustrating the rapid progress which has been made within the past few years in photographing stellar spectra. The first figure, which is a direct copy of the spectra obtained in 1885, was taken with the Voigtländer lens of two inches aperture having a 30° prism in front of it and shows the spectra of α Lyræ, α Aquilæ, α Bootis and β and γ Ursæ Majoris ; the instrument having been directed successively to these stars and the plate exposed five minutes on each. The longest of these spectra is not over four millimeters in length. The second figure is the spectrum ζ Ursæ Majoris accompanied by that of an adjacent fifth magnitude star. It was taken with the larger Voigtländer lens, with an exposure of five minutes. It is about nine millimeters long and one wide, and illustrates the size of spectra used in preparing the catalogue of spectra of the brighter stars, one or two hundred of these being sometimes photographed on a single plate. The third figure represents the spectrum of α Lyræ, and was taken with the Draper eleven-inch telescope with two prisms, on November 5, 1886, with an exposure of fifty-nine minutes. This spectrum is a little more than fifty millimeters long and about two and a half millimeters wide. The fourth spectrum, taken on January 21, 1887, represents β Geminorum. The exposure was fifty minutes, four prisms being used with the eleven-inch Draper telescope. This spectrum is nearly eighty millimeters long. All these now described are original negatives printed by contact. The fifth figure in this plate represents a little more than half of the spectrum of β Geminorum (as given in figure four) enlarged by Prof. Pickering's special process above described. This spectrum is 220 millimeters long and seventy-five wide, and shows a mass of dense lines irregularly distributed. Below this is a narrow strip, fifteen millimeters wide, of the spectrum of the same star taken on January 12th. It is given for comparison and shows that practically all of the lines shown belong really to the star itself and are not produced in the photographic processes.

It is gratifying to know that Mrs. Draper has been so well satisfied with these splendid results that she has decided greatly to extend the original plan of the work and to have it conducted in the future on a scale suited to its importance. The attempt will be made to include all portions of the subject so that the final results shall form a complete discussion of the constitution and conditions of the stars as revealed by their spectra, so far as scientific methods at present permit. It is expected that a station will be established in the southern hemisphere, so as to permit the work to be so extended that a similar method of study may be applied to stars in all parts of the sky. The investigations already undertaken include (1) a catalogue of the spectra of all stars north of 24°, of the sixth magnitude or brighter, (2) a more extensive catalogue of spectra of stars brighter than the eighth magnitude, and (3) a detailed study of the spectra of the

bright stars. This last will include a classification of the spectra, a determination of the wave-lengths of the lines, a comparison with terrestrial spectra and an application of the results to the measurement of the approach and recession of the stars. A special photographic investigation will also be undertaken of the spectra of the banded stars and of the ends of the spectra of the bright stars. Beside the instruments already mentioned, there will be used the twenty-eight-inch and fifteen-inch reflectors constructed by Dr. Draper, which Mrs. Draper has decided to send to Cambridge for this purpose, and also the fifteen-inch refractor belonging to the Observatory.

From these statements it will appear that photographic apparatus has here been provided on a scale quite unequaled elsewhere. "But," says Prof. Pickering, "Mrs. Draper has not only provided the means for keeping these instruments actively employed, several of them during the whole of every clear night, but also of reducing the results by a considerable force of computors and of publishing them in a suitable form. A field of work of great extent and promise is open, and there seems to be an opportunity to erect to the name of Dr. Henry Draper a memorial such as heretofore no astronomer has received. One cannot but hope that such an example may be imitated in other departments of astronomy, and that hereafter other names may be commemorated not by a needless duplication of unsupported observatories but by the more lasting monuments of useful work accomplished."

Note added May 1, 1887.

The excellent phototype plate which accompanies and illustrates this paper, shows the enlarged positives of the spectra of α Tauri taken with two prisms and that of o Ceti taken with one. The negatives from which the phototype plate was prepared were kindly furnished me by Prof. Pickering especially for this purpose. My obligations are due to him, therefore, for this courtesy. I am also indebted to Mr. Gutekunst for the faithfulness of their reproduction.

It is a gratifying evidence of appreciation of Prof. Pickering's photographic work, that the National Academy of Sciences, at its meeting in Washington, in April, awarded to him the Henry Draper gold medal, for having in their opinion made the most important progress in Astronomical Physics during the two years which have elapsed since the preceding award.

Dr. Frazer made the following remarks:

A question suggests itself in relation to the very important results of Prof. Pickering, which Prof. Barker has so lucidly and interestingly described.

As the extremely minute point of light which is received on the first prism represents the radiation from every part of the star under examination, of course the line of light produced by the prism will represent at any infinitesimal fraction of time, the whole radiation of light from the

half of the star turned towards us during that time ; and during an indefinitely short exposure might be said to represent the condition of the surface visible to us as it was during a certain minute time interval when the waves set out from that surface. [Neglecting for the moment the modification of this statement which the curvature of the star's surface would render necessary owing to the fact that the light which proceeded from the extreme outer edge would have a longer distance to travel than that in the centre by a little more than the radius of the star, and therefore its arrival at the instrument might be later than that from the central portion.]

But the broadening of this line into a surface by making a slight difference between the rate of the clock-work and the angular motion of the earth, would represent this same elongated surface of the star at different times. In other words the one axis would represent different parts of the star at the same instant of time, and the other axis would represent the same region (the hemisphere visible to us) at different periods of time.

If the movements of the atmosphere of the star observed were as rapid and extensive as those of our own sun, the consequence would be that we would have a succession of different conditions of the star's atmosphere placed in close juxtaposition, the whole series representing all the changes that had occurred in the star's photosphere during the interval of exposure. On this account it would seem that this method was not adapted to do more than give the resulting average of these changes on a sensitive plate of measurable breadth and would not permit the condition of the photosphere at any one instant of time to be studied.

It would be interesting to know what effect a similar procedure on the disc of the sun would show, by juxtaposing a large number of instantaneous photographs of the disc as different parts of the latter were successively brought over the slit of the spectroscope.

Notes on the Surface Geology of South-west Virginia. By John J. Stevenson.

(Read before the American Philosophical Society, May 20, 1887.)

New river, rising in North Carolina, flows across the Archæan area of Virginia, and enters the "Great Valley" of that State in Wythe county. It flows through Wythe and Pulaski counties, separates the latter from Montgomery, and flows through Giles county into West Virginia on its way to the Ohio river at Point Pleasant. It drains the counties named, with the addition of Bland. The most important forks of the Holston river flow through Smyth and Washington counties of Virginia into Tennessee ; while the Clinch river rising in Tazewell county of Virginia flows through Russell and Scott counties and drains much of Wise. It is joined in Tennessee by Powell river, which drains Lee county and part of Wise.